Endovascular repair of descending thoracic aortic aneurysms: an early experience with intermediate-term follow-up

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Purpose: The purpose of this study was to report an initial experience with the endovascular repair of descending thoracic aortic aneurysm. Complications and intermediate-term morphologic changes were identified with the intent of altering patient selection and device design.
Methods: Endografts were placed into 25 patients at high-risk for conventional surgical repair over a 3½–year period. Devices were customized on the basis of preoperative imaging information. Follow-up computed tomography scans were obtained at 1, 3, 6, and 12 months and yearly thereafter. Additional interventions occurred in the setting of endoleaks, migration, and aneurysm growth.
Results: The overall 30-day mortality rate was 20% (12.5% for elective cases; 33% for emergent cases). There were 3 conversions to open repair. Neurologic deficits developed in 3 patients; 1 insult resulted in permanent paraplegia. Neurologic deficits were associated with longer endografts (P = .019). Three endoleaks required treatment, and 1 fatal rupture of the thoracic aneurysm treated occurred 6 months after the initial repair. Migrations were detected in 4 patients. The maximal aneurysm size decreased yearly by 9.15% (P = .01) or by 13.5% (P = .0005) if patients with endoleaks (n = 3 patients) were excluded. Both the proximal and distal neck dilated slightly over the course of follow-up (P = .019 and P = .001, respectively). The length of the proximal neck was a significant predictor of the risk for endoleakage (P = .02).
Conclusion: The treatment of descending thoracic aortic aneurysms with an endovascular approach is feasible and may, in some patients, offer the best means of therapy. Early complications were primarily related to device design and patient selection. All aneurysms without endoleaks decreased in size after treatment. Late complications were associated with changing aneurysm morphologic features and device migration. The morphologic changes remain somewhat unpredictable; however, alterations in device design may result in improved fixation and more durable aneurysm exclusion. (J Vasc Surg 2000;31:147-56.)

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Competition of interest: nil.
Materials were supplied free of charge by W.A. Cook Europe, A/S, Bjaeverskov, Denmark; Schultzer-Vascutek, Scotland; and Boston Scientific–Meadox, Oakland, NJ.
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0741-5214/2000/$12.00 + 0 24/1/101472

The morbidity and mortality rates associated with the conventional surgical approach to thoracic aortic aneurysms has driven physicians to seek improved and less invasive methods of caring for these patients. Physiologic monitoring devices and the use of partial or complete cardiopulmonary bypass with and without hypothermic circulatory arrest are all relatively recent medical advances that assist in the treatment of patients with aneurysms that were previously deemed unresectable. Despite these great strides, conventional approaches to thoracic aneurysms often have debilitating or fatal outcomes.[1-3] The evolution of endovascular technology offers the promise of a new, less invasive method of

achieving aneurysm exclusion. Although this therapy is restricted to patients with aneurysms that contain proximal and distal landing zones, overall patient selection may actually broaden when treatment is offered to those individuals whose comorbid conditions may preclude open surgical repair.

The goal of endoluminal repair is to provide durable exclusion of the aneurysm sac while minimizing the morbidity and mortality rates of the procedure. Despite the theoretic advantages offered by an intraluminal approach, the treatment of aneurysms must be viewed in context of the patient's life expectancy and risks of interventions. Incisions remote from the pulmonary musculature, the limited tissue dissection, and the absence of aortic crossclamping diminish the operative risks; stent-graft and delivery device complications are substantial, and the long-term outcome is unknown. Our experience with the development of endovascular prostheses designed for the thoracic aorta has brought to light a number of conceptual issues. Furthermore, follow-up information provides us with an initial framework from which we can assess protection from rupture and the need for additional interventions.

MATERIAL AND METHODS

Patients. The hospital ethics committee approved the endovascular procedure. Informed consent was obtained from all patients or patient families. A team of vascular surgeons, thoracic surgeons, and interventional radiologists provided patient care. All procedures were performed in Sweden at either Malmo University Hospital or Lund University Hospital. Twenty-five patients were enrolled between 1993 and 1997.

Preprocedural imaging. In the absence of hemodynamic instability, potential candidates for endoluminal repair underwent both spiral computed tomography (CT) scanning and angiography. The CT protocol consisted of reconstructions performed at 3-mm increments from a protocol using a collimation of 5 mm and a table speed of 5 mm / sec. A total of 150 mL of 300-mg noniodinated contrast agent was administered at a rate of 3 mL / sec. Angiography was conducted with calibrated catheters to assist with length measurements. The morphologic condition of the aneurysm (with regard to the subclavian and celiac arteries, concomitant occlusive disease, and other arterial anomalies) was given careful consideration. The pelvic vasculature was assessed with both CT scanning and angiography to determine the feasibility of delivery system introduction. Emergent cases were imaged with spiral CT scans only.

Inclusion criteria. Unacceptable aneurysm morphology was the most common source of patient exclusion. Proximal necks were required to have a relatively normal interval of 15 mm between the subclavian artery and origin of the aneurysm. In 2 cases carotid–subclavian bypass grafts were performed, allowing us to place the stent-graft over the orifice of the subclavian artery, thus lengthening the region of proximal fixation. A 2-cm supraceliac aortic segment was required for distal fixation. Proximal and distal aortic diameters of up to 38 mm were treated. Large amounts of thrombus in the fixation regions, conically shaped necks, and extensive disease of the pelvic vasculature were relative contraindications for endovascular repair. Mycotic aneurysms and acute dissections without aneurysmal changes were not treated in this protocol. Overall, 60% of patients reviewed for endovascular repair were deemed acceptable candidates and treated with an endovascular approach.

Endograft design and construction. Stent-grafts were customized to fit patient anatomy as depicted by axial CT images, three-dimensional reconstructions, and angiography. Axial images were used to determine diameter measurements, although stent-graft diameters were oversized by 10% to 15%. The length of the endoprosthesis was determined by an assessment of the calibrated angiographic images. The prostheses were designed to cover stents extending 1.5 cm beyond the confines of the aneurysm in both proximal and distal directions. Proximal and distal accessory extension grafts were constructed before each procedure, should they be required during the initial repair.

The endoskeleton of the graft was comprised of Gianturco Z-stents (W.A. Cook Europe, A / S, Bjaeverskov, Denmark). The configuration of the stents evolved as we gained experience with the procedure. The initial three implants contained a proximal and distal stent that extended slightly beyond the graft material. The remainder of the graft material was not fully supported. Shortly thereafter, the configuration was altered to a fully supported system. Individual Z-stents were affixed to the graft material with Gortex CV-6 suture (W.L. Gore, Flagstaff, Ariz), leaving 2- to 3-mm spaces between stents. During the latter one half of our experience, we used longitudinally continuous Z-stents fashioned together in a spiral configuration. The proximal stent, in all cases, included four sets of caudally oriented barbs and cranially directed hooks to aid with proximal fixation. The graft material used was an ironed woven polyester graft (Cooley Veri-Soft; Meadox Medicals Inc,

Oakland, NJ). The free edges were heat sealed to prevent unraveling. The completed product was then sterilized with a steam autoclave system before it was placed within the delivery device.

Delivery system. The delivery system consisted of a sheath, a central cannula, and a suture loop used to stabilize the proximal end of the prosthesis during deployment. The size ranged from 20F to 24F, depending on the dimensions of the stent-graft. To deploy the endograft, the outer sheath is retracted after satisfactory positioning. The inner cannula is then withdrawn, completely releasing the looped sutures, thus freeing the stent-graft from the delivery system. The fixation of the endograft to the delivery system confers stability during deployment against the column of blood that flows through the thoracic aorta, which allows for more accurate positioning.[4]

Device deployment. All procedures were performed in the operating room with the patient under general anesthesia. Imaging consisted of a portable C-arm unit (Siremobil 2000; Siemens, Erlangen, Germany) with both digital subtraction and roadmapping capabilities. Preparation of the artery used to introduce the stent-graft system required open surgical exposure with circumferential mobilization. Small iliac vessels (<7.5mm in diameter) with severe occlusive disease mandated a retroperitoneal approach to the common iliac artery or the aorta. The common femoral artery was used in 21 patients; the external iliac artery was used in two patients, and the infrarenal aorta was used in two patients who underwent simultaneous repair of infrarenal abdominal aortic aneurysms. A stiff guide wire was placed into the aortic arch after the administration of heparin (100 IU/kg body weight). The contralateral groin was accessed percutaneously to allow the performance of intermittent contrast angiography (Omnipaque 200-300 mg/mL; Nycomed, Oslo, Norway) during deployment. When the proximal stent was noted to be in a satisfactory location, the sheath was slowly withdrawn using intermittent small bursts of contrast from the neighboring angiographic catheter to ensure completely accurate positioning. After deployment, the endograft remained fixed to the delivery device until the inner cannula was withdrawn. Incomplete stent expansions were treated with balloon dilatation. Completion angiography was performed, and the arteriotomies were closed under direct vision with 5-0 or 6-0 polypropylene suture.

Follow-up. Routine surveillance included anteroposterior and lateral chest radiographs and contrast-enhanced spiral CT scans. Interval examinations were performed at 1, 3, 6, and 12 months after the operation and yearly thereafter. Aortography was performed only in the setting of suspected stent-graft migration, abnormal perfusions detected by other imaging modalities, or progressive aortic dilation. All films were reviewed by at least two physicians from the team.

Statistical analysis. The Student *t* test was used to assess for significant differences associated with graft length and paraplegia. A general linear model was used to evaluate the changes in aortic diameter with respect to follow-up time and for any association between neck length, aneurysm size, and endoleak incidence.

RESULTS

Twenty-five patients underwent endovascular repair of thoracic aortic aneurysms between June 1994 and December 1997. Age, at the time of presentation, ranged from 47 to 87 years (mean, 74 years). Descriptive characteristics pertaining to patient presentation, aneurysm cause, and comorbid factors are listed in Table I. Marked variations in the overall size and morphologic condition of the aneurysms were noted and are described in Table II. The operative time and requirements for blood products decreased as we gained experience with the procedure.

Complications

Deaths. Our procedures were complicated by five perioperative (within 30 days) deaths. Two patients who had undergone elective repair died. The first patient underwent a combined repair of thoracic and abdominal aneurysms. The extreme tortuosity of the aorta mandated the placement of a brachial catheter and wire in addition to wire access from below. A left subclavian artery dissection was noted in this patient after the endovascular repair, which likely resulted from tension placed along the brachial catheter and wire during device delivery. The patient died suddenly 14 days after the operation from a questionably related intracranial hemorrhage. The second death also resulted from a combined procedure consisting of an open infrarenal aortic aneurysm repair and an endovascular thoracic aortic aneurysm repair. This patient had a massive distal embolization and died on postoperative day 4.

Three patients who underwent emergent endovascular repair for ruptured thoracic aneurysms died. One of these patients had a complete twist in an unsupported graft early in our experience, resulting in aortic occlusion and death. Extreme aortic tortuosity (Fig 1) in a second patient mandated the performance of a minithoracotomy (although an aortotomy was not

Table I. The comorbidities of each individual case are listed in conjunction with the acute (within 30 days of the procedure) and chronic complications

Comorbidities	*Complications*	
	Acute	*Chronic*
Elective cases		
CAD, COPD, polio	None	None
CAD, small AAA	None	Migration
Parkinsons, polymyalgia rheumatica	None	None
COPD	Paraplegia	Paraplegia
Refused open surgery	None	Migration
COPD, previous lung resection	None	None
Previous TAA resection, empyema	None	Death, TAA rupture*
Simultaneous endovascular TAA and AAA repair	Death, conversion	Death
COPD	Groin hematoma	None
CAD, CVA, cecal carcinoma	None	None
Simultaneous endovascular TAA and AAA repair	Death	Death
CAD, COPD, prior AAA resection	Conversion	None
COPD, AAA	None	None
CAD, s/p AAA resection	None	Endoleak
Two prior CABG procedures, AAA, angina	None	Migration
Refused open surgery	None	Migration
Emergent cases		
Aortobronchial fistula, third operation for aortic coarctation	None	None
Refused open surgery, contained rupture	Death	Death
Attempted prior TAA resection, contained rupture	Conversion, death	Death
CAD, symptomatic	None	None
CAD, chronic renal insufficiency, contained rupture	Death	Death
Multiple blunt trauma, coagulopathy	None	None
CAD, acute dissection with contained rupture	None	None
Multiple blunt trauma, coagulopathy	None	None
COPD, colon carcinoma	None	Endoleak

CAD, Coronary artery disease; *COPD*, chronic obstructive pulmonary disease; *AAA*, abdominal aortic aneurysm; *TAA*, thoracic aortic aneurysm; *CVA*, cerebrovascular accident; *s/p*, status post; *CABG*, coronary artery bypass grafting.
*The proximal stent in this patient ruptured through the superior aspect of the aortic arch, resulting in death.[5]

Table II. Morphologic characteristics of the thoracic aorta and stent-graft design

Morphologic characteristics (mm)	*Aneurysm (mm)*	*Stent-graft*
Neck diameter	29.6 ± 3.7	35.0 ± 3.8
Neck length	74.0 ± 41.7	N/A
Overall length	93.8 ± 53.4	165.2 ± 72.5
Maximum aneurysm diameter	68.8 ± 17.9	N/A

N/A, Not applicable.

required, this is described as a conversion in Table I) and excessive vascular manipulation in an effort to assist the advancement of the delivery device. This patient died of massive distal embolization shortly after the procedure. The third death in this group resulted from a myocardial infarction on postoperative day 4.

Three patients died during the follow-up period. A single patient died of a rupture 6 months after the initial procedure. The patient was noted to have an endoleak on the first follow-up CT scan. This was further evaluated with angiography, determined to be a proximal endoleak, and treated with balloon dilation. Follow-up CT scanning depicted no evidence of perigraft flow. Three months after this procedure, the patient had symptoms of rupture and died during the resuscitation. The autopsy examination demonstrated erosion of the proximal stent through the superior aortic wall just distal to the subclavian artery.[5] A second death resulted from a rupture of a remote (ascending aortic) aneurysm 6 months after successful endoluminal repair of a descending thoracic aneurysm. The third death, which occurred 20 months after the procedure, was unrelated to aneurysmal disease and attributed to metastatic carcinoma.

Conversion to open repair. Three patients underwent emergent conversion to an open surgical approach. Immediate distal migration of the stent-graft that resulted in occlusion of the celiac and superior mesenteric arteries necessitated conversion. A proximal aortotomy was performed under hypothermic circulatory arrest. This allowed the endograft to

be pulled into the appropriate position and the proximal anastomosis to be constructed with conventional techniques. The patient experienced a transient paraparesis, which resolved 12 hours after the procedure after the placement of a spinal drainage catheter. Two patients required minithoracotomies. One procedure was to control hemorrhage from an aortic perforation, and the second procedure was to assist with proper positioning of the stent graft delivery device in an extremely tortuous vessel (Fig 1). Neither of these patients required aortic crossclamping.

Paraplegia. Permanent bilateral motor and sensory deficits occurred in one patient. This patient had sequential aneurysms of the thoracic aorta requiring the use of a 21-cm endograft. Paralysis was noted immediately after the surgical procedure and did not improve with adjunctive treatments. Two cases of transient paraperesis were noted. The first patient, who has been discussed previously, had a ruptured aneurysm with an improperly deployed stent-graft that required emergent conversion to open repair. The second case was noted after the placement of an extension graft for the treatment of a distal endoleak 4 months after the initial procedure. The paraperesis was transient, resolving completely within 24 hours. A comparison of total graft lengths in the three patients with neurologic symptoms (mean graft length, 240 mm) to survivors without evidence of neurologic compromise (mean graft length, 121 mm) yielded a significant difference ($P = .019$).

Endoleaks. Despite the detection of four intraoperative endoleaks, only three endoleaks were noted on postoperative imaging studies. One patient died of postoperative complications before additional treatment. One patient underwent reballooning of the proximal graft that resulted in a seal; however, she died shortly thereafter of the rupture of the proximal stent through the superior aspect of the aorta. Distal endoleaks were noted in two patients during the follow-up period. One patient was treated successfully with coil embolization (Fig 2); the second patient was not treated because the patient had recently been diagnosed with metastatic carcinoma.

Stent-graft migration. Careful scrutiny of postoperative imaging studies revealed four cases of stent-graft migration. Migration was defined as movement of the stent-graft greater than 5 mm with respect to the vertebral body in a proximal or distal direction. Three distal stents were noted to have migrated proximally. One patient required the placement of a distal extension to maintain aneurysm exclusion. A fourth patient demonstrated migration of both the proximal and distal stent toward each other (Fig 3). The patient has refused further procedures; however, the aneurysm has remained excluded. The migrations were noted in patients who received either form of the fully supported (continuous spiral and noncontinuous) Z-stent design.

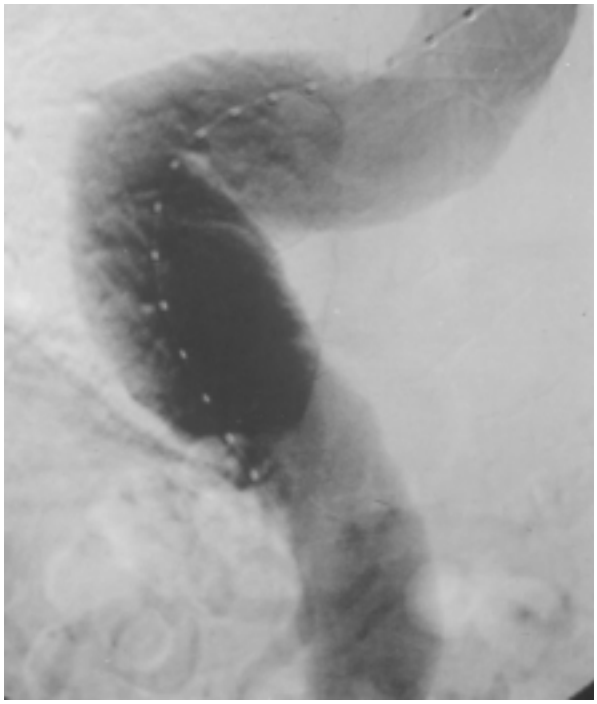

Fig 1. This intraoperative angiogram was performed during the treatment of a contained ruptured aneurysm. The tortuosity of the aorta precluded access to the upper portion of the descending thoracic aorta. A minithoracotomy was performed to assist with access. Despite the accurate placement of the device with complete aneurysm exclusion, the patient experienced massive distal embolization and died shortly after the procedure. This amount of tortuosity, with or without atheromatous debris, is now viewed as a contraindication to endovascular repair.

Follow-up. A careful evaluation of all survivors with thoracic aneurysms of nonspecific cause (n = 15 patients) over a mean period of 15.4 months (range, 3-30 months) yielded some interesting findings. All patients were available for follow-up. If we were to exclude those patients with detectable endoleaks, the maximal aneurysm size decreased 13.5% per 12-month period ($P = .0005$). Both the proximal and distal necks dilated significantly over the course of follow-up period ($P = .019$ and $P = .001$, respectively); however, the absolute values were quite small (in the range of 1-2 mm). A short proximal neck was a significant predictor of the risk for endoleakage (50.2 mm vs 84.6 mm; $P = .02$).

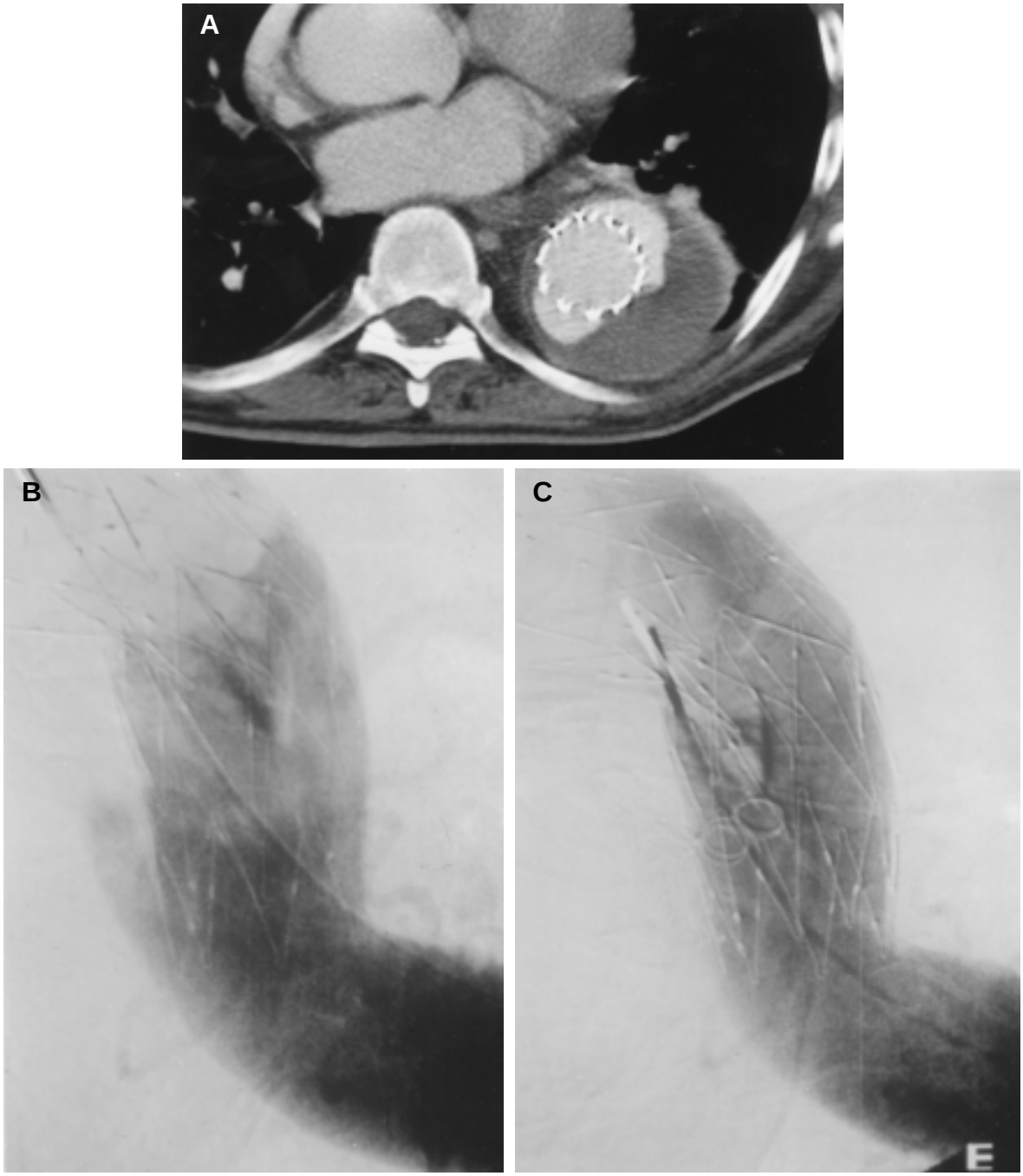

Fig 2. This distal endoleak was detected on the 3-month CT scan (A) and further evaluated with angiography (B). Coil embolization was performed with a radiographic seal of the leak (C). However, although there is no evidence of perigraft flow, it may be possible that the aneurysm would still be exposed to systemic pressures transmitted through the thrombus.

DISCUSSION

Although conceptually simple, endovascular repair of descending thoracic aneurysms has the potential to be extremely difficult. The development of the technique has occurred largely in patients who were felt to be incapable of surviving conventional surgical procedures. The extreme morbidity of this patient population has had a profound influence on

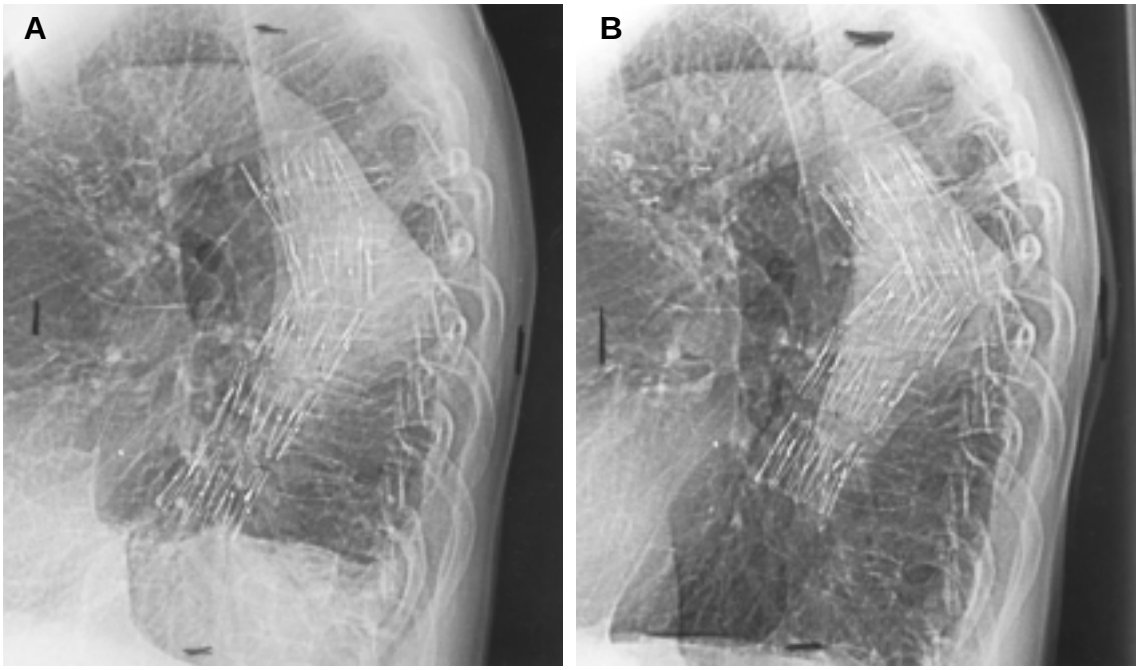

Fig 3. These two lateral chest films were taken 12 months apart. A, Note the position of the proximal and distal stents with respect to the vertebral bodies. On the follow-up examination (B) the proximal stent has migrated distally, and the distal stent has migrated proximally. Although the aneurysm remained excluded, continued migration would surely result in an unprotected state.

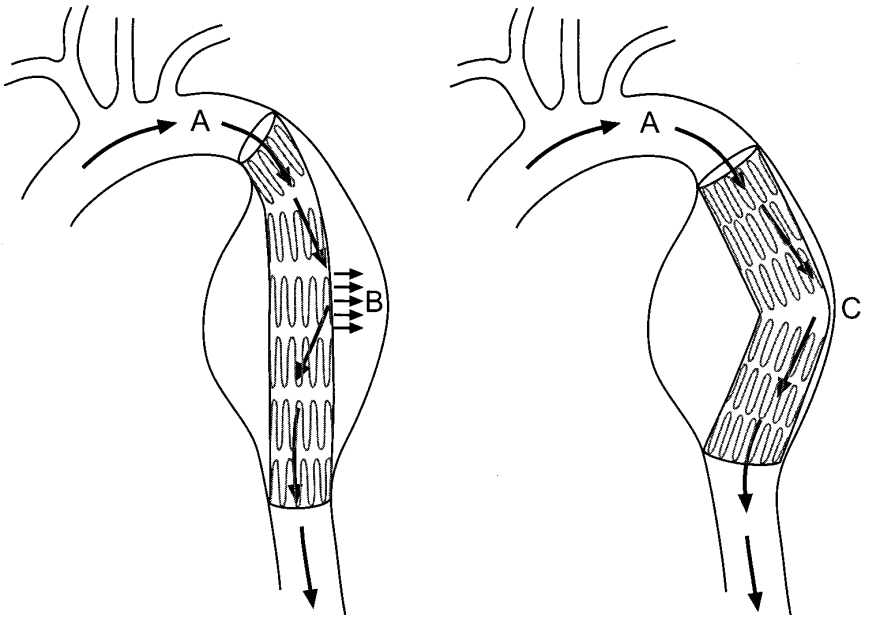

Fig 4. This diagram shows the forces of a column of blood traveling into the descending thoracic aorta (*A*) that will exert a force on an endovascular graft in the mid-descending aorta (*B*) because of the curvature typically seen in the descending thoracic aorta. The force, into the middle of the stent-graft, drives the endograft into the aneurysm, pulling upward on the distal stent and downward on the proximal stent. The result is telescoping of the graft (*C*), with the potential to expose the aneurysm sac to systemic pressures (Fig 3).

the outcome of endovascular procedures. The group from Stanford University has published an uncontrolled trial with 103 patients who underwent endovascular repair of aneurysms of the descending thoracic aorta.[6-8] They experienced a 9% mortality rate, and the major morbidities consisted of three cases of paraplegia, four atheroembolic cerebrovascular events, and one case of late aneurysm rupture.

Most of these patients were deemed "high risk" for conventional surgery. They were uniformly assigned an American Society of Anesthesiology class of 3 or 4, given the severity of their co-morbid conditions (Table I). The perioperative mortality rate in our series was 12.5% for patients who underwent elective repair and 33% for those patients who required emergent endovascular repairs. However, the only perioperative deaths in patients who underwent elective endovascular repair occurred in the setting of combined abdominal and thoracic procedures. Despite the fact that few of these patients were candidates for open repair, most of the complications were attributable to the endovascular procedure. Access problems, early delivery device failure, and graft-related issues accounted for four of the five deaths, all of which are largely preventable with the use of more recent device designs and modifications that we have made to our selection criteria. The structural evolution of the device paralleled the complications we encountered. The adaptation of a fully supported system was prompted by the patient who had a complete aortic occlusion after a complete 360-degree twist of the endograft. The addition of longitudinal support imparted by the spiral attachments improved the deployment characteristics and conferred columnar strength. Modifications made to the delivery device occurred as a result of difficulty in manipulation through tortuous vessels and the single case of aortic perforation. Fixation of the endograft to the delivery device provides added accuracy during deployment and obviates the need to induce temporary cardiac arrest or hypotension as advocated by other authors.[9,10] Increased flexibility was accomplished by changing the inner metal core to a coaxial system with 7F and 4F catheters. The two patients who died of massive distal embolization are now recognized to have been unsuitable for endovascular repair, and we have subsequently excluded similar patients with extremely tortuous vessels or significant amounts of atheromatous debris visible on axial images within their aortas. Additionally, we are deterred from performing simultaneous repairs of abdominal and thoracic aneurysms because of the two deaths in this patient subgroup and reports of other similar experiences.[11]

Of the three late deaths in this patient group, two of the deaths were unrelated to aneurysm repair. The third death was, however, from a rupture of the excluded aneurysm 6 months after the operation. The tortuosity of the aortic arch in this patient resulted in unfavorable positioning of the proximal portion of the stent-graft. A proximal endoleak was noted on immediate postoperative imaging studies; however, a CT scan performed at 3 months revealed no evidence of a leak. The autopsy determined the cause of rupture to be the erosion of the proximal stent through the aortic arch. This finding has implications in patient selection but should cause one to carefully consider the use of long Z-stents in the relatively steep angle normally present in the region of the subclavian artery orifice. Additionally, the stent that ruptured through the aortic wall was uncovered, potentially allowing for an unequal distribution of force on the aortic wall. A shorter, more flexible design with forces distributed equally will better serve this patient population. However, the inherent dichotomy created by the desire to have increased flexibility while maintaining adequate radial force and proximal fixation poses design issues. Because the length of the Z-stent decreases, a diminished radial force is coupled with increased flexibility. A balance must be struck between these two characteristics. Fixation of the endograft to the delivery device is critically important for a number of reasons. Deployment accuracy is dramatically increased, because the downward force applied by the column of blood in the thoracic aorta is countered by the secure positioning of the delivery device. Minor adjustments and the immediate distal migration, as we observed in a single patient who required conversion to open repair, can be made after deployment of the main body of the graft.

The three patients who experienced the development of neurologic deficits all had endografts that were significantly longer than the remaining 22 patients. This is not surprising, owing to the surgical literature, where the highest rate of paraplegia has been noted to occur with repair of the most extensive aneurysms. However, given the absence of aortic crossclamping and minimal hemodynamic instability, a careful evaluation of larger numbers of patients undergoing endovascular repair may help us differentiate the causes of paraplegia. Clearly, partial bypass grafting techniques and intercostal reimplantation will not play a role in this patient population. However, the use of spinal drainage and cooling methods may be more easily evaluated in the absence of other confounding variables.

Endoleaks should be viewed with great trepidation in the thoracic aorta. All of the three endoleaks that we noted during the follow-up period were associated with a failure of the aneurysm to decrease in size. Every aneurysm that was noted to have a complete seal on postoperative axial imaging decreased in size. We conclude that, to offer protection from rupture, one must halt the progression of aneurysmal dilation and that all endoleaks must be treated. The use of coils to provide an adequate seal in the region of inadequate attachment sites remains unproven and may not provide adequate protection, as suggested by the Sydney group's description of endotension[12] and further questioned by the Montifiore group.[13] However, in the single case where we applied this therapy to treat a distal leak, the aneurysm was noted to decrease in size after the procedure. The placement of extensions is clearly more definitive in the repair of attachment site leaks; however, their use must be viewed judiciously because of the strong association with overall graft length and paraplegia. Interestingly, we have seen no cases of persistent perfusing vessels. Hypothetically, we would expect 2 to 3 patients with perfusing vessel endoleaks, given an equivalent number of patients with infrarenal aortic aneurysms treated with an endovascular approach. Proximal and distal neck dilation was noted to occur to a small but significant extent. This may be due to the placement of a self-expanding stent in that region of aorta; however, analogous observations have been noted in the infrarenal aorta.[14,15]

Migration, as we noted in 4 of the 25 patients, is also a cause for extreme concern. The youth of endovascular grafting may offer a false sense of security with regard to the long-term stability to the various devices we implant. With respect to endovascular repair, a mid-descending saccular aneurysm is the easiest to exclude. However, we found that the distal stent in the mid to lower portion of the descending thoracic aorta has a relatively high potential as an explanation (Fig 4). The influence of these observations on endograft design should prompt the use of more adequate fixation of both the proximal and distal stents. The caudally oriented barbs we have used on the proximal stent have increased both in number and in size. Furthermore, cranially oriented barbs on the distal stent, despite complicating deployment mechanisms, may offer additional protection against proximal migration. Although we have not seen evidence of significant periaortic tissue injury in animal models[16] or our series of patients, it may warrant further evaluation.

The use of endoluminal grafting to treat descending thoracic aortic aneurysms is feasible but associated with significant complications. The use of improved delivery systems and better graft design will help to diminish the incidence of perioperative complications that we encounter. Careful patient selection should improve results with regard to embolization. The presence of an endoleak is indicative of an unprotected aneurysm and should be treated aggressively. Spinal cord ischemia remains a significant problem with both endovascular and conventional repair; however, the lack of aortic crossclamping and relative hemodynamic stability of the patients treated with an endovascular approach eliminates some variables that have confounded studies that assessed many of the contributory factors associated with paraplegia. Perhaps new light will be shed on the problem by the evaluation of a group of patients without intercostal artery reimplantation who do not undergo the physiologic derangements brought about by significant aortic clamp times or partial bypass grafting. New endograft designs with improved mechanisms of fixation should eliminate the problems associated with migration; however, alterations in overall aortic morphologic condition will have to be carefully studied. The intermediate-term data indicate that all successfully excluded aneurysms should decrease in size, and extreme concern is advocated should this not occur.

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Submitted Apr 29, 1999; accepted Jun 30, 1999.